US DEPARTMENT OF ENERGY SOLID STATE LIGHTING 2008 MULTI-YEAR PLAN **TECHNOLOGY R&D**

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Lighting in the Big Picture

- By 2025, DOE's goal is to reach technology capability for a net-zero energy building ("ZEB" and a net-zero home, "ZEH")
- Lighting contributes 25% of energy consumption in commercial buildings and 12% in residential
- Saving half the lighting energy – the SSL goal – would contribute substantially to ZEB and ZEH

SSL's Multi-year Plan

- The MYPP spells out how to reach the goal
  - Chapter 4 is the Technology R&D Plan
- Performance targets (and status) in four flavors:
  - Conversion efficiencies (independent of spectrum)
  - Overarching *device* targets for efficacy, lifetime, cost
  - *Luminaire* targets
  - Detailed and specific subtask metrics and targets

- Many participate in developing the Plan, including the NGLIA, this workshop, and DOE managers

What Happened in 2007?

- LED efficacies far-surpassed our projections
- Several high quality LED luminaires appeared in the market (and a few not so good, too)
- Prices more attractive (apparently)
- OLED efficacies improved exponentially

Consequences for the MYPP

- Higher near-term efficacy targets for LEDs
- New emphasis on luminaire performance
- New milestone for LEDs
- Some redirection of resources (task priorities)
- Continue OLED track for efficacy
- Additional cost and reliability effort for OLEDs

Device conversion efficiency

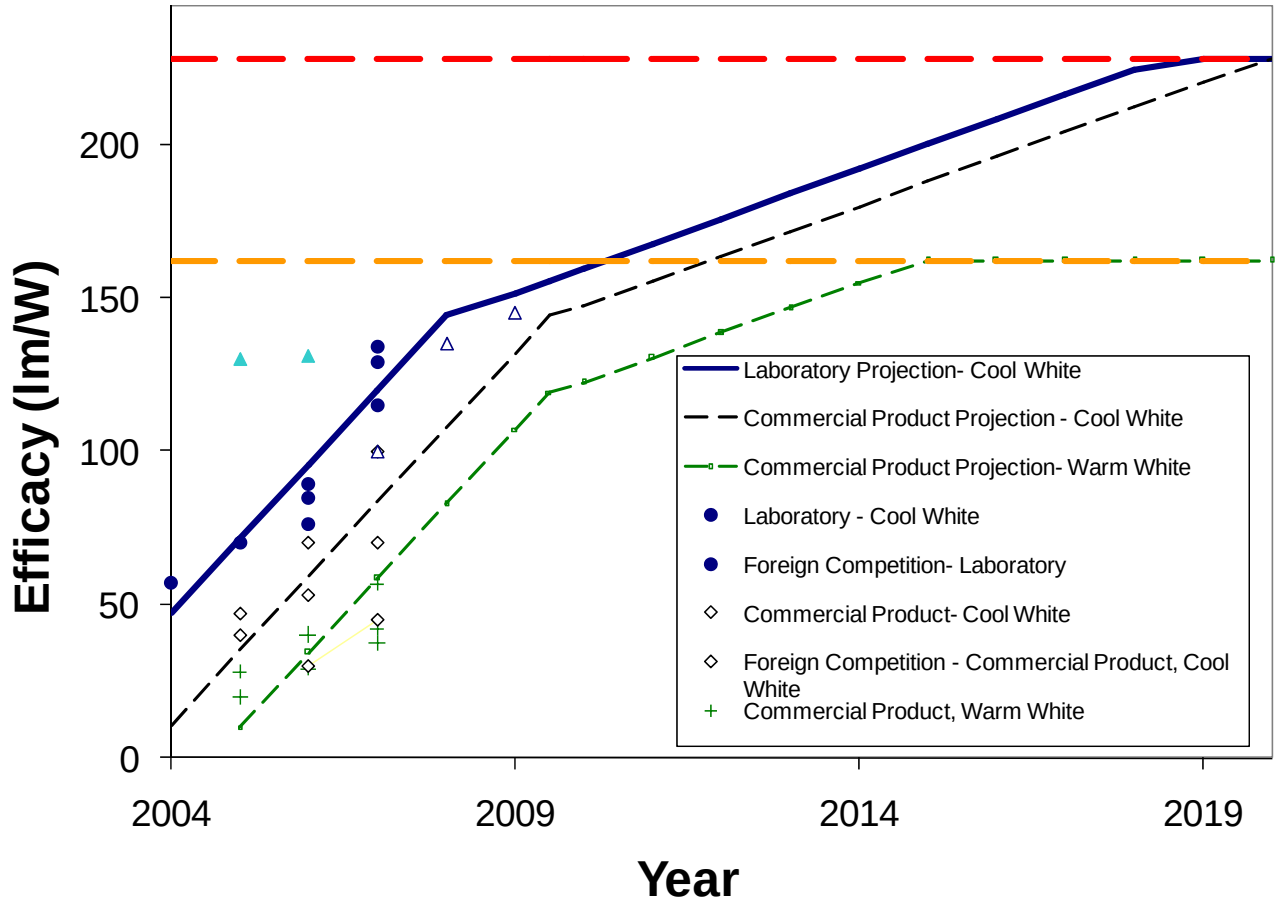
- Bottom line *device efficiency* targets:
  - Color mixing LED device – 66% target
    (~27% in 2007, up from 16% in 2006)
  - Phosphor LED device – 48% target
    (~25% in 2007 up from17%)
  - OLED device – 69% target
    (~11% in 2007 up from 9%)
- Reflects energy savings, but…
- Conversion alone does not alone make for useful light (measured by efficacy)

Reaching LED Efficacy Limits?

- Efficacy depends on
  - Correlated color temperature (CCT)
  - Color quality (CRI)
  - Conversion efficiency
- Estimated maximum practical values assume
  - a "good" spectrum
  - about 50% conversion
- These are rough asymptotes for LEDs

Maximum LED Efficacy (lumens/ Watt)		
CCT	75 CRI	90 CRI
3000K	182	162
4100K	220	193
6500K	228	186

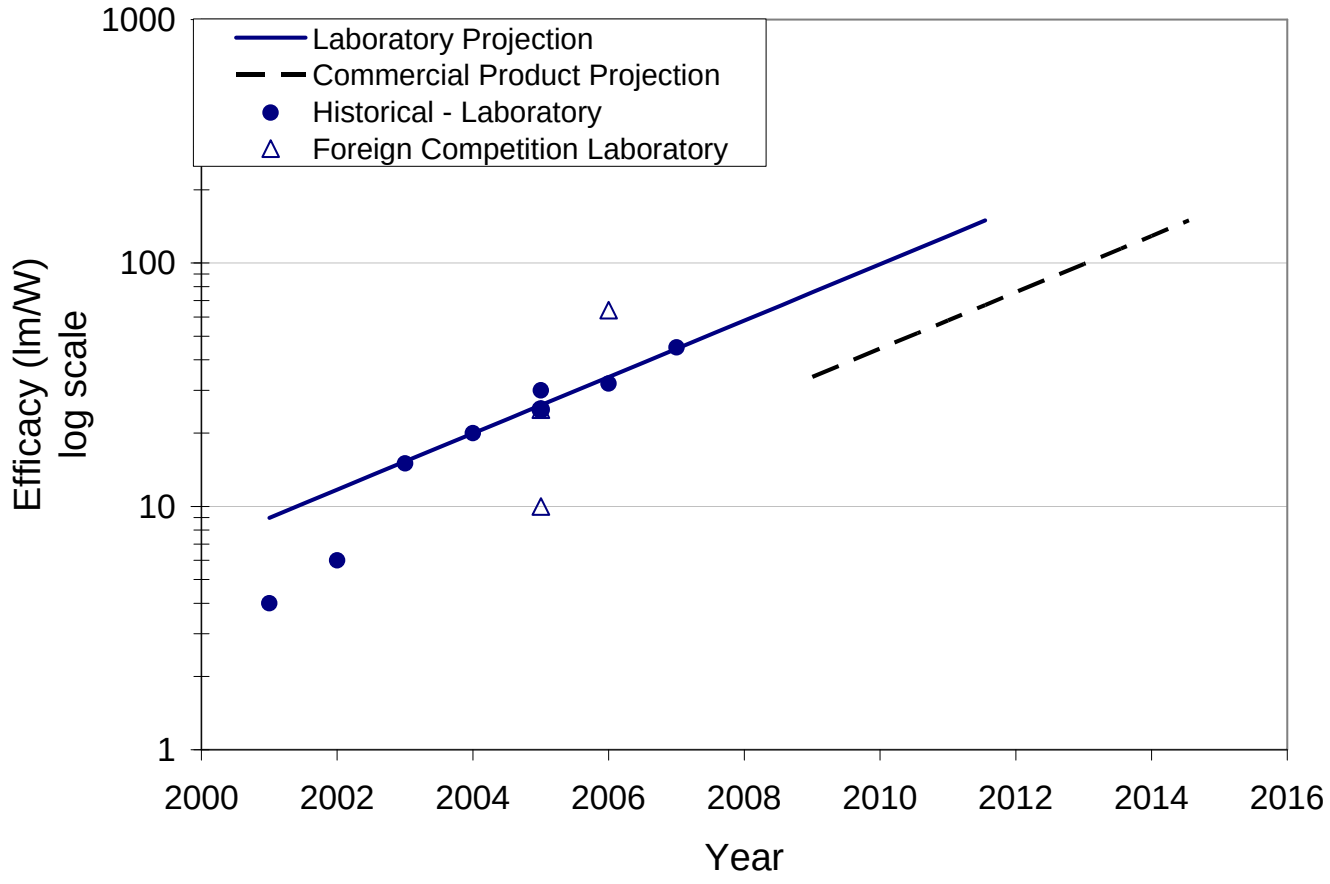
LED Efficacy Goals



LED Device Performance Track

Metric	2007	2010	2012	2015
Efficacy- Lab (lm/W)	120	160	176	200
Efficacy- Commercial Cool White (lm/W)	84	147	164	188
Efficacy- Commercial Warm White (lm/W)	54	117	134	158
OEM Device Price-Product ($/klm)	25	10	5	2

OLED Efficacy

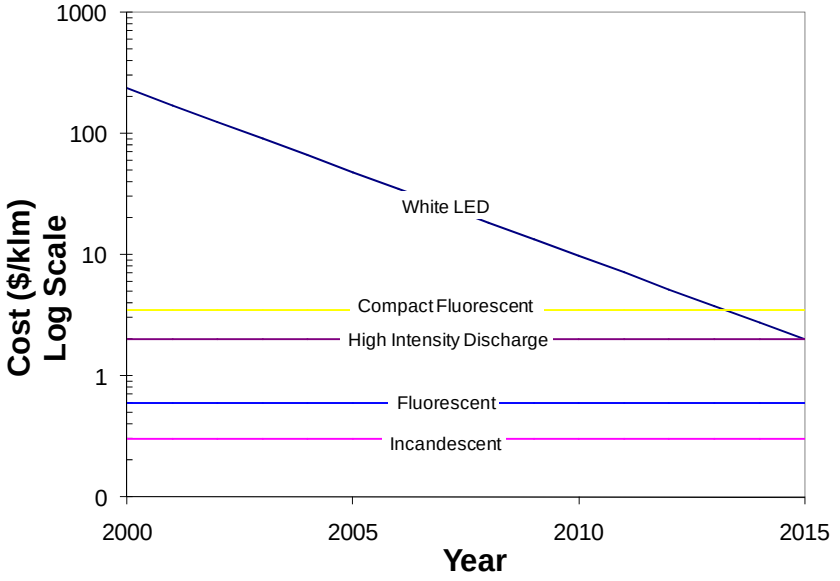


OLED Device Performance Track

Metric	2007	2009	2012	2015
Efficacy- Lab (lm/W)	44	76	150	150
Efficacy- Commercial (lm/W)	N/A	34	76	150
OEM Device Price- ($/klm)	N/A	72	27	10
OEM Device Price- ($/$m^2$)	N/A	216	80	30
Device Life- Commercial Product (1000 hours)	N/A	11	25	40

LED Device Costs

- Device costs are still a barrier to deployment
- But costs are falling rapidly
  - Chart compares LED *devices* to conventional *lamps* (a bit overly optimistic but instructive)
  - LEDs should approach cost parity within planning time period



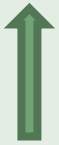
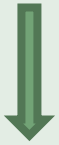
Luminaire Targets

Efficacy (lm/W)	LED		OLED	
	2007	2015	2009	2015
Device	84	188	34	150
Luminaire	47	161	27	129

Priority Changes: LED Core

Priority	Subtask
Higher ↑	1.3.2 Encapsulants and packaging materials
	1.4.x Inorganic growth, fabrication process, mfg. research
Lower ↓	1.1.3 Reliability and defect physics..
	1.1.1 Large area substrates….
	1.2.2 Strategies for improved light extraction…

Priority Changes: LED Product Development

Priority	Subtask
Higher 	2.3.3 Power Electronics Development
Lower 	NONE

Priority Changes: OLED Core

Priority	Subtask
Higher ⇕	3.3.2 Low-cost encapsulation and packaging technology
Lower ⇕	3.1.3 Improved contact materials and surface modification….

Priority Changes: OLED Product Development

Priority	Subtask
Higher ⇕	NONE
Lower ⇕	NONE

Product Milestones for LEDs

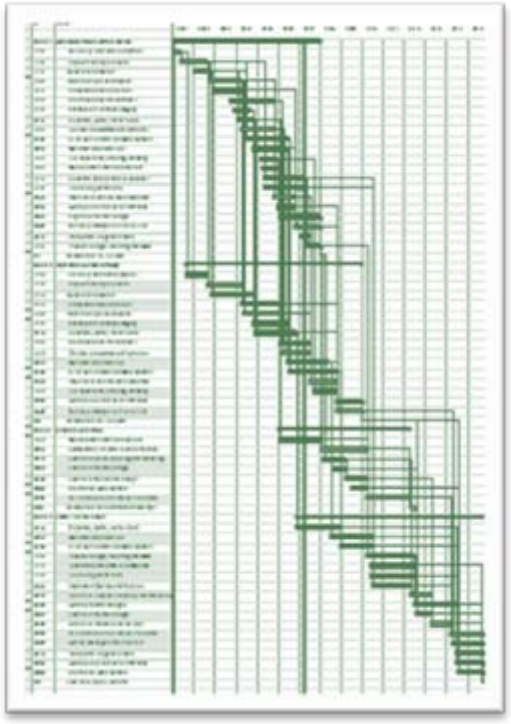
Milestone	Year	Target
Milestone 1	FY08	80 lm/W, < $25/klm, 50,000 hrs device
Milestone 2	FY10	> 140 lm/W cool white device; > 90 lm/W warm white device
Milestone 3	FY12	126 lm/W luminaire that emits ~1000 lumens
Milestone 4	FY15	< $2/klm device

Product Milestones for OLEDs

Milestone	Year	Target
Milestone 1	FY08	25 lm/W, < $100/klm, 5,000 hrs device
Milestone 2	FY10	<$70/klm device cost
Milestone 3	FY15	> 100 lumen/Watt device

Critical Path Analysis

- Critical path analysis
  - Helps focus resources
  - Easily updated from results
  - A work in progress
- Critical tasks for LEDs
  - High efficiency emitters
  - Good packaging materials and design
  - Thermal issues/luminaire integration
- OLED chart is in the works



LED Milestone #1 has been passed – on time

Conclusion: What We Hope to See in 2008

- High-power LED device on the market delivering >100 lm/W
- A luminaire product offering that provides 1000 lumens at 65 lm/W
- A white OLED lighting product on the market with reasonable efficiency, cost and life
- LED device costs below $10/klm
- And more!

Credits

- Thanks to the NGLIA participants…
  - Joseph Shiang, GE Global Research
  - Anil Duggal, General Electric
  - Dietrich Bertram, Philips
  - Jianzhong Jiao, Osram Opto Semiconductors
  - Steffan Zahn, Air Products and Chemicals
  - Ann Norris, Dow Corning Corporation
  - Angela Hohl-AbiChedid, Osram Sylvania
  - George Craford, Philips Lumileds
  - Kevin Dowling, Philips Solid-State Lighting Solutions
  - Paul Phillips, LSI Industries
  - Ralph Tuttle, Cree, Inc.
  - Anant Setlur, GE Global Research
  - Srinath Aanegola, GE Lumination

Credits

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  - Diana Burk
  - Mahima Gupta
  - Brinda Thomas
- Also, our other consultants….
  - Paul Burrows, PNNL
  - Morgan Pattison, Solid State Lighting Services, Inc.
- And to you, for your participation and feedback

Please email comments to *fredwelsh@verizon.net*